U.S. Department of Agriculture Agricultural Research Service
April 1983

Agricultural Research

Tillage— A Fascinating Evolution

"The problems facing agriculture do not come in neat and tidy packages," Terry B. Kinney, Jr., Administrator of ARS, says in discussing the mission of the agency. History also tells us that the more important the problem, the less tidy the package.

One important part of the new ARS Program Plan—to sustain food and fiber production—is the conservation of soil and water. Tillage, marked by a fascinating evolution in practice and theory, still is not a "neat" package, but it is one of the basic elements of soil and water research.

If we are to judge by paintings on the walls of 5,000-year-old Egyptian tombs, a plow may have been one of the first tillage implements. The paintings show oxen yoked together by the horns, drawing a forked tree. The Greeks added a metal point to replace the forked tree, and there were no major changes until American Colonial days. The colonists, largely dependent on the soil, constructed a plow with a wooden frame, a moldboard covered with iron strips, and a curved iron cutting point.

But tillage theories probably began with an Englishman named Jethro Tull, considered by agricultural historians to be the father of modern tillage. He published a book called *Horseshoeing Husbandry* (1731) in which he said, "Tillage is manure."

His theory, highly controversial in his lifetime, was that cultivation loosened the soil particles that then fed the plant. In some respects, Tull's 18th century "manure theory" comes close to conservation tillage concepts in 1983, some of which are the subject of research at the National Tillage Machinery Laboratory in Auburn, Ala.

Conservation tillage, growing in popularity, has been defined as any means of working the earth which reduces loss of soil or water. It includes several different tillage systems that leave enough residue on the land's surface to reduce or stop its erosion.

In this country, residue from field crops—manure, in a sense—amounts annually to about 400 million tons from 413 million acres.

Many farmers are attracted to the conservation tillage concept. Conservation tillage can help save soil, reduce water pollution from chemicals following erosion and runoff, and save fuel and time. Other farmers, seeing disadvantages such as investing in a particular kind of planter and depending more heavily on herbicides, are less attracted.

For example, researchers at the Coastal Plains Soil and Water Conservation Research Center, Florence, S.C., report that minimum tillage has a fairly broad level of acceptance in the southeastern Coastal Plains, while no-till is less widely accepted. However, interest in no-till is growing, and farmers are concerned with ways to make it work.

Certainly conventional tillage has a long and honorable history, and there is no easy way to estimate how many farmers are ready for or even require new approaches. In fact, to some extent conservation tillage is a refinement of conventional tillage, because machinery is necessary in most conservation tillage systems.

Briefly, some of many conservation tillage systems are *no-till; eco-fallow* when a row crop follows a grain crop; *sod planting* when referring to forage-crop farming; *strip-till; rotary-till* if the strip is opened through residue with a rotary tiller (for vegetable crops); *ridge-plant* if a narrow strip is made with a pair of coulter disks that create a ridge; *disk-and-plant; chisel-disk-plant;* and a new system called *slit-plant,* in which the compacted soil layer is penetrated with a narrow slit to make room for roots. The slit-plant tillage system was originated by researchers at the National Tillage Machinery Laboratory and is undergoing further testing and evaluation.

These systems are a departure from plowing or primary tillage, which loosens and aerates the soil, turns it over to cover trash and weed seeds and exposes fresh soil ready for the harrow. Harrows refine the seedbed, level the plowed soil, compact it, and destroy weed seedlings. Cultivators destroy weeds, and chisel plows break up compacted soils for deeper root growth.

Manure spreaders and distributors for commercial fertilizers feed the plant. And (shades of Jethro Tull) stalk cutters and rotary cutters may mix crop residues with the soil, although they have other uses.

Tillage, however it is "packaged," is almost never neat and tidy. Its practice may often be enriched by common sense, such as the real or apocryphal answer to the question: Why have 38- and 40-inch rows been used so long for planting and plowing? These dimensions are roughly equivalent to the space a mule needs to pass between them.

Peggy Goodin
New Orleans, La.

Contents

Agricultural Research
Vol. 31 No. 10
April 1983

Editor: Jean M. Rawson
Acting Assistant Editor: Joan Blake
Photography Editor: Robert C. Bjork
Art Director: Deborah Shelton
Circulation Manager: Charles Jones

Agricultural Research is published monthly by the Agricultural Research Service (ARS), U.S. Department of Agriculture, Washington, D.C. 20250. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through March 31, 1987. Send subscription orders to Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Information in this magazine is public property and may be reprinted without permission. Prints of photos are available to mass media; please order by month and photo number.

Magazine inquiries should be addressed to: The Editor, Information Staff, Room 318, Bldg. 005, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705. Telephone: (301) 344-3280.

John R. Block, Secretary
U.S. Department of Agriculture

Orville G. Bentley
Assistant Secretary
Science and Education

Terry B. Kinney, Jr.
Administrator
Agricultural Research Service

Cover: At the National Tillage Machinery Laboratory in Auburn Ala., ARS scientists and engineers are developing concepts for tillage and traction systems that could make farming operations far more efficient—and more customized—than ever before. Article begins on p. 8. (1078X1246-8)

245 ARS Network Aids Agricultural Exports [2-4]

Grain is poured into a barge on the Missouri River. Research is finding ways to fumigate grain on board ships to reduce insect losses—to help U.S. grain sales stay competitive with those from other countries. (1074A1641-31)

The export of U.S. farm products, a powerful economic force on the world market, has strong and nourishing roots in agricultural research. As far back as 1910, then Secretary of Agriculture James Wilson said, ". . . more and more attention is being directed to the study of the handling of perishable products, that waste may be lowered and quality and condition improved. . . The results already obtained show the great value and importance of such studies in the conservation of our finished (farm) products—the most valuable asset of any people."

Today, ARS research continues to have strong links with the robust state of America's farm exports. One of the highest achievements of agricultural research is the ability to get an abundance of perishable products in salable condition to markets thousands of miles away.

But, ironically, people are infinitely more aware of onfarm research results—corn hybrids that have tripled yields, or chicken and turkey breeding that has led to flourishing poultry industries—than they are of advances in what is now referred to as "postharvest technology."

In the long run, however, results of postharvest research are important: For every American growing food in 1980, four others were processing, storing, transporting, or marketing it.

Since 1910 and before, ARS scientists have conducted research to improve packaging materials, find insect-free storage methods, and develop more efficient, less expensive ways to transport farm products to foreign and domestic markets.

Current Agriculture Secretary Block, like Secretary Wilson, counts on research continuing to make high-quality American farm products available. New world-trade fields sown with U.S. farm goods will surely be fertilized with timely research.

Some ARS projects deal with exporting emergencies, such as the outbreak of Mediterranean fruit flies in California in 1981 that closed Japan to all shipments of California fruit.

Other projects make long-range improvements in marketing key export commodities. Ongoing studies of stored grain insects, for example, help keep U.S. grain shipments competitive with grain from other countries.

However, despite long-range and emergency projects, most ARS scientists aiding exports do so by solving short-term problems on a case-by-case basis.

Such research often begins at the European Marketing Research Center in Rotterdam, the Netherlands. Two scientists at Rotterdam operate at the gateway of Western Europe, our best regional customer for farm goods since World War II.

The Center was founded in 1969 in response to requests by U.S. growers, shippers, and trade associations for assistance in exporting. By evaluating test shipments from stateside researchers, and providing onsite technical marketing data to exporters, the Rotterdam scientists have nurtured many commodity markets. Annual exports worth $12 million in Texas grapefruits, $2 million in radishes, and $1.5 million in lettuce and Chinese cabbage have resulted largely from the efforts at Rotterdam.

"If we exported nails by way of Rotterdam rather than farm products," says Roy McDonald, staff scientist for horticultural postharvest quality, "we would not need scientists there. I mean, if nail crates split on arrival, importers tell shippers, stronger crates are found, and a market is saved. Simple. But, farm products are living matter, perishable in a thousand ways. Because people tend to eat with their eyes, importers will not accept deformed or off-color goods."

Assigned to Rotterdam from 1974 to 1979, McDonald says scientists there help keep U.S. farm products competitive in foreign markets by monitoring arrival conditions of a wide range of commodities.

Take the case of leatherleaf ferns—an important agricultural item from Florida, which as recently as 1978 often arrived in Europe with heat or cold damage. Claims against U.S. shippers reached 40 percent of all arrivals.

However, researchers at the Market Quality and Transportation Laboratory at Orlando, Fla., cooperating with the

scientists at Rotterdam, designed new packages and stowage patterns for shipping leatherleaf ferns, and pinpointed the best temperatures and other conditions for shipping. As a result, U.S. commercial shippers reduced claims to 2 percent by 1980 and boosted sales from $1 million to over $9.2 million.

Typically, Rotterdam scientists or agricultural attachés with the USDA's Foreign Agricultural Service (FAS) identify a particular marketing problem. Then, the scientists work with an ARS domestic laboratory to find a solution. Test shipments are made, often in cooperation with a commercial shipping company. The goods are evaluated at the Rotterdam lab. Data are sent back to the stateside laboratory. A back-and-forth trial system develops until a better product is clearly possible. Recommendations are then published and are thus available on an equal basis to U.S. exporting companies.

Sometimes scientists at Rotterdam use comprehensive surveying, rather than new laboratory work, to expand markets. Case in point, variety meats: Beef and pork kidneys, tongues, livers, and other so-called variety meats are considered by many Europeans to be a valuable protein source.

In 1978, the FAS attaché in the United Kingdom told researchers at Rotterdam of importers' complaints of the poor conditions of frozen U.S. variety meats. A $60 million U.K. market for U.S. variety meats was in jeopardy from superior New Zealand products.

William Miller, ARS agricultural marketing specialist at Rotterdam, learned from major European importers, steamship companies, port health authorities, and others that the eye-appeal of U.S. variety meats was perhaps the poorest of variety meats coming into Europe. Importers discounted U.S. variety meats to sell them.

To keep British complaints from jeopardizing our entire European market, Miller conducted extensive interviews with 48 European buyers, handlers, and users of U.S. variety meats. Many said the quality of our meats was excellent, but packaging was bad. Handling U.S. variety meat packages was difficult, they said, because there were no standard package sizes and weights.

Miller's published findings are now available to the U.S. meat industry, which is adjusting marketing strategies. The result of Miller's surveying, according to McDonald, is that variety meats are one of two recent Rotterdam efforts most likely to expand export markets. The other? Specialty fruit.

When medflies appeared in California in 1981, Japan refused to import fruit from California growers. Immediately responding to the problem, ARS accelerated its research on fumigation methods acceptable to the Japanese—who remain among the best customers for U.S. farm products. (1175X2245-28)

Kiwi fruit, blueberries, and other so-called specialty fruits are in high demand in Europe. Kiwi fruit from California, however, meets stiff competition in Europe from New Zealand and French kiwi fruit.

Cooperating with the Rotterdam Center, scientists at the ARS Market Quality and Transportation Laboratory in Fresno, Calif., are winnowing out possible causes for inferior quality of U.S. kiwi fruit arriving at European ports. Shippers want to know why they can't stay competitive with kiwi fruit from more distant shores. The answers will be interesting in that a top quality U.S. kiwi could at least corner European markets during the Southern Hemisphere winter—peak season for the California kiwi fruit.

To expand blueberry exports, we compete only with our own ingenuity. Almost all blueberries sold commercially are grown in North America.

At the going price of up to $5 a half pint in Europe, blueberries are a potential big export item for U.S. growers and shippers. Until recent ARS research findings, however, shipping fresh blueberries to Europe has been limited to air freight. In 1981, scientists at the Postharvest Research Laboratory in New Brunswick, N.J., conducted test shipments of fresh blueberries to Europe by ocean carrier. The blueberries were cooled after harvest and kept at 36°F in transit, then sold in excellent condition to European wholesalers—the first commercial sea shipment ever successfully completed.

Almost exclusively a North American crop, highly perishable blueberries like these could become a big item for export to Europe. ARS scientists have found new ways to ship blueberries fresh and "explosion-puffed." (0874X1413-3A)

In Philadelphia, scientists at the Eastern Regional Research Center recently demonstrated that blueberries can be "explosion-puffed," stored for 2 years, then reconstituted to near fresh form and taste. Explosion-puffing may considerably expand markets for the U.S. blueberry (see *Agricultural Research*, July-August 1982, p. 12).

In Asia, Japan is our best customer for agricultural products, annually importing $150 to $180 million in U.S. citrus alone. However, in 1981, Mediterranean fruit flies made their infamous appearance in California, our top fruit-producing

Papayas from Hawaii are prepared for shipment to Japan. Keeping perishable products in salable condition while transporting them to markets thousands of miles away is a direct result of strong research programs in post-harvest technology. (0774X1222-24)

State. Japan ceased all importing of Golden State produce.

The USDA's Animal and Plant Health Inspection Service (APHIS) declared a quarantine on all fruit grown within the 81 square miles where the medflies were found. However, Japan (a major importer of California citrus) considered the entire State under quarantine, although no medflies were found in the citrus-farmed southern parts of the State.

"The ARS reaction to the medfly situation was to accelerate studies to fumigate fruit with approved chemicals in ways to meet new, tougher restrictions imposed on our shippers by the Japanese," says Milton Ouye, staff scientist for commodity treatment for insects.

"For example, we are developing onboard treatments for fruit. Instead of delaying fruit at departure docks for many days, an entire shipload is fumigated during the 12-day journey to Japan," Ouye said.

In December 1982, ARS scientists announced new cooling technology for shipping grapefruits that could be used as a substitute for fumigating fruit with ethylene dibromide (EDB). The refrigeration technique for grapefruit could save a $90-million-a-year export market to Japan, if EDB is banned by the U.S. Environmental Protection Agency, which is scheduled to make such a decision public in July 1983. (The fumigant has been implicated as a possible cancer-causing agent.)

Such research is conducted in a maze of complex regulations. ARS studies support APHIS and State regulatory agencies, who together set and enforce quarantines (when necessary, with the cooperation of FAS and the Federal Grain Inspection Service).

Though complex, the process has opened or reopened many commodity markets recently, including:

- A $2 million market in Japan for Northwest cherries. ARS research on cold temperature fumigation convinced Japanese officials to reform regulations that for 4 years had limited market potential.
- A $7 to $10 million export market in Japan for timothy hay. The market closed when Japanese quarantine inspectors found prohibited plant materials in timothy from Washington State. The plant materials were species known to harbor the Hessian fly, another U.S. pest not present in Japan. Research on fumigation to kill the fly in timothy hay convinced Japanese officials to reaccept U.S. shipments, provided the hay is fumigated under guidelines of the new research and verified by APHIS.

As for medfly-related research, "So far, it has been a resounding success," says APHIS technology analysis and development staff officer Charles M. Amyx. "The Japanese are now accepting fruit from nonregulated areas, those outside of our original 81-square-mile quarantine. The work continues, but we have already saved growers millions of dollars."

As at Rotterdam, where scientists study U.S. exports at the marketplace, ARS research to ease export restrictions is only conducted for large blocks or categories of goods. More specific marketing research, display, pricing, psychology, advertising, and the like is, of course, conducted and paid for by private firms.

In general, postharvest research is conceived and managed to aid both foreign and domestic marketing of our farm goods. However, through such research, an abundance of food and fiber is available for exporting. A future example of such spillover could result from current research on hogskins, which due to recent changes in pork packing, are only now becoming marketable.

At ARS labs in Philadelphia, U.S. and French scientists are developing ways to make hogskins suitable for leathermaking in Western Europe's tanning industries. Little interest exists in America for hogskin processing. Therefore, success of the project could mean valuable European markets.

In 1910, Secretary Wilson reported that the value of farm exports had "increased to the enormous amount" of $1 billion in 1908 only to fall to $871 million in 1910. Could he have dreamed the figure would be $167 billion by 1979? Considering that Wilson was aware of the "unsung" importance of postharvest research, perhaps the answer would be, "Yes, of course."

Roy McDonald is located at the Horticulture Research Laboratory, 2120 Camden Rd., Orlando, Fla. 32803. Milton Ouye is located in Rm. 218, Bldg. 005, Beltsville Agricultural Research Center-West, Beltsville, Md. 20705.—(By Stephen M. Berberich, Beltsville, Md.) ■

100

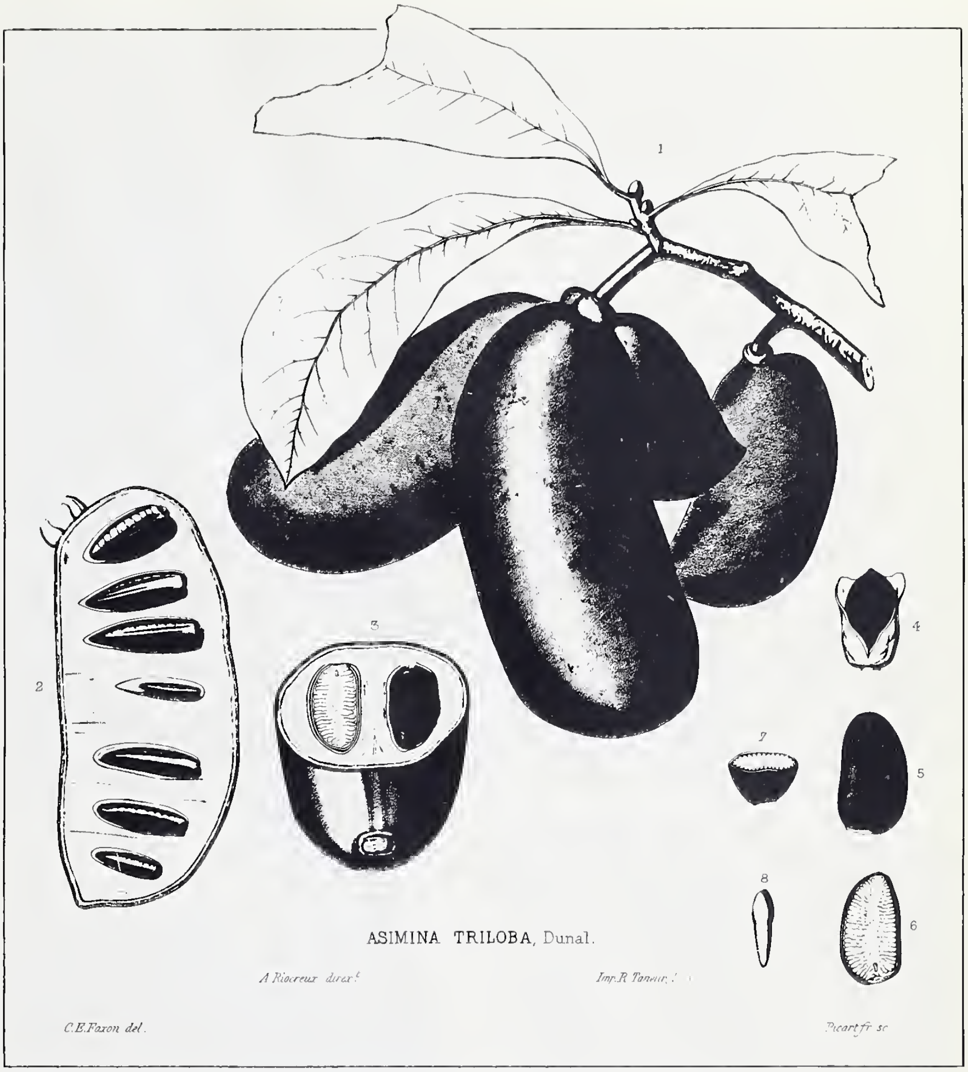
Adopting a Horticultural Orphan

Not all valuable fruit is grown in cultivated orchards. In fact, one, the American pawpaw, a horticultural orphan, may emerge as one of our most valuable fruit trees.

Pawpaw (*Asimina triloba*) is potentially the most important wild fruit in the United States. Its neglect remains something of a mystery because the fruit has a fragrant aroma, the custard-like texture of a banana, and the rich sweet taste of a pear. Yet, from the standpoint of improvement through cultivation and attraction of scientific interest, it remains virtually unknown.

However, all native American foods—wild or cultivated—have had an uphill battle for acceptance. This is true of such present-day staples as corn, beans, squash, tomatoes, and potatoes. For instance, the blueberry, before 1930, was an undomesticated fruit seldom found in markets outside New England. Its now widespread acceptance is the result of USDA's research and development.

Little was known about the food value of pawpaw until chemist John P. Cherry began his analysis of its nutritive value (the first such nutrient study since 1917) at ARS's Southern Regional Research Center in New Orleans, La. Cherry had been contacted by R. Neal Peterson, an agricultural economist with the Economic Research Service, who has been instrumental in developing the potential of the pawpaw as a tree crop.



Botanical drawing of pawpaw *(Asimina triloba)* from *Silva of North America*, published in 1890. (PN-7045)

Cherry found pawpaw fruit to have high nutritional quality, especially when compared to apples, peaches, and grapes. Unusually low in moisture content, the pawpaw is high in unsaturated fats, proteins, and carbohydrates.

Pawpaw is an excellent source of vitamins A and C. The vitamin A content of pawpaw is comparable to apples and grapes. Although pawpaw contains less vitamin C than citrus fruits, it has more than double the amount found in apples, peaches, or grapes.

Cherry also found that the pawpaw contains higher amounts of potassium, phosphorus, magnesium, sulfur, and iron than the other three fruits.

Pawpaw's protein contains an exceptionally good balance of the amino acids that are essential to the human diet. In fact, the pawpaw has up to six times the amount of amino acids found in apples, peaches, and grapes.

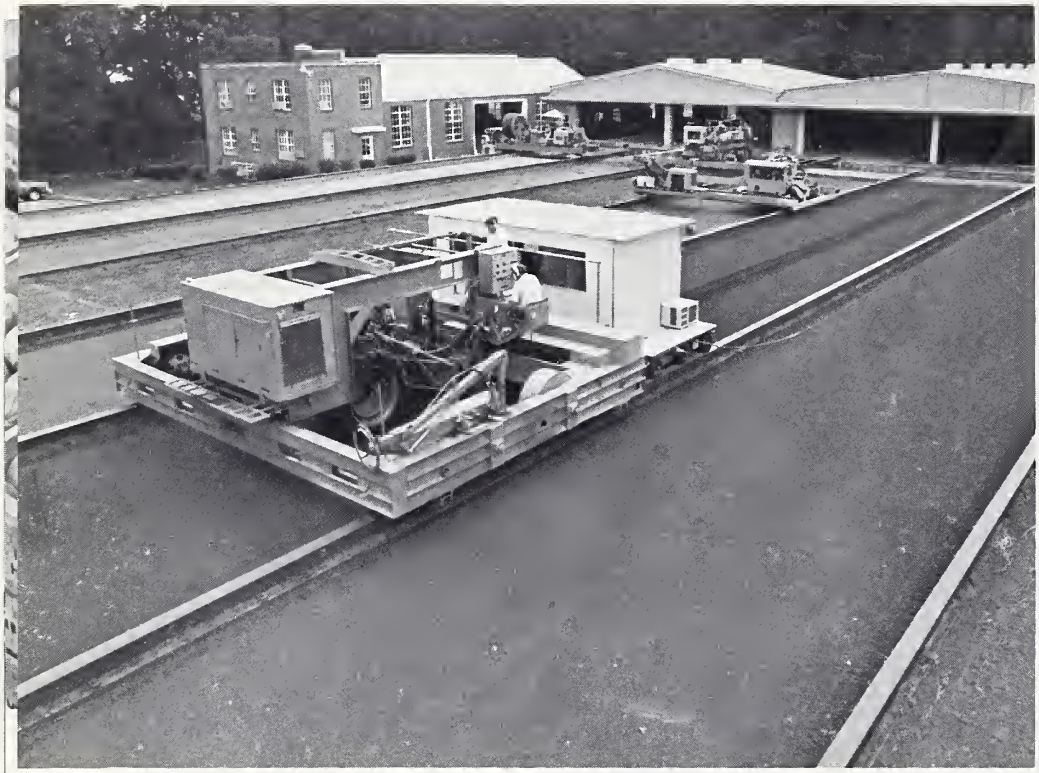
Cherry and Peterson believe research efforts to domesticate the pawpaw should concentrate on propagation techniques, cultural practices, shipping and handling methods that would prolong storage life, and the selection of superior varieties. The pawpaw has a diverse germplasm which should allow for improvement through breeding and selection.

"The pawpaw is found in virtually all of the Eastern United States and extends as far north as southern Michigan. It shows an adaptability that should suit it to cultivation in all temperate, humid regions of the world," says Peterson.

Presently grown mainly as a novelty by a few home gardeners, the pawpaw is a hardy tree with attractive foliage that is not bothered by insects or disease and is tolerant of shade. Such characteristics make the species most suitable to intercropping in a tree-crop style of agriculture, for controlling erosion, and for commercial orchard production.

John P. Cherry, formerly with the Southern Regional Research Center, is now located at the Eastern Regional Research Center, 600 East Mermaid Lane, Philadelphia, Pa. 19118. R. Neal Peterson is located at the National Economics Division, Economic Research Service, 500 12th St., S.W., Washington, D.C. 20250.—(By Neal Duncan, New Orleans, La.) ■

Tillage: Ancient Practice, Modern Challenge



Facilities at the National Tillage Machinery Laboratory include nine outdoor and two indoor soil bins for evaluating tillage and traction machinery concepts in various soil conditions. As instrument-laden platforms move along rails separating the bins (1078X1248-25A), their operators keep in touch with a central control station—here monitored by electronic technician Jack Jarrell, who checks data from platform operated by agricultural engineer Eddie Burt. (0383X191-3)

Science has made modern agriculture one of the wonders of the world, but tillage remains more of an art than a science. Even now, experts occasionally disagree as to what the precise purpose of tillage is. In an area of study that produces phrases tirelessly—no-till, reduced-till, eco-till—no single phrase or image catches this complex activity in all of its parts. Nevertheless, the practice, or habit, of tillage is as old as agriculture itself, and agriculture is older than civilization.

Tillage grew out of a human need to take an active part in securing the essentials of life—food and fiber—rather than waiting passively for fickle nature to supply them. Tillage is not the whole of agriculture. But the technology that began thousands of years ago when the first farmers dug the earth with sharpened sticks to grow food for themselves and a few others has progressed to the point where the American farm worker, using sophisticated machines driven by powerful tractors, produces enough food to feed 70 people.

So, with this amazing achievement, why not stop where we are and call it good enough? Because it is not good enough. Some tillage operations are wasteful of energy, and the soil may be left vulnerable to erosion. Topsoil, which takes thousands of years to form, is eroding from some areas of our land at unacceptable rates. For these and other good reasons, the old "blanket" cultivation in which large areas of land are plowed, disked, and harrowed, without much thought to the specific needs of the crop or the needs of the land itself, is under close scrutiny. In fact, we are seeing the evolution of concepts that, along with new equipment designs, will radically transform the practice of tillage.

Agricultural engineer Robert L. Schafer, director of the ARS National Tillage Machinery Laboratory, Auburn, Ala., and colleagues, have given a lot of thought to the fact that modern tillage lacks a unifying vision. They think they have found one.

"Too often," says Schafer, "tillage systems are combinations of operations applied in a broad manner without regard for all the needs of the plant or for conservation. Future tillage systems must be much more specific than present systems. Specific crops, soil types, and environments must receive their own special treatment."

They call this holistic concept "Custom Prescribed Tillage." CPT focuses on the crop production needs for tillage rather than on tillage tools. It means that a specific crop on a specific soil must be tilled in a prescribed manner, taking into account all the environmental variables. In other words, an excellent practice in one place may be a disaster in another. In Schafer's view, future tillage systems will control the application of energy to produce the specific soil conditions needed in crop production, such as excellent water infiltration, aeration, and resistance to erosion.

All this does not mean that we totally abandon the moldboard plow. Some soils must be plowed, and that is not always a simple task. A great deal of land in the United States, and much more in the rest of the world, is a very fertile but heavy, sticky clay that is the very devil to work. With this soil in mind, Schafer helped develop and test

a lubrication concept that made working the heavy clay soil possible.

Says Schafer, "We were able to work soils that could not be tilled with the conventional moldboard plow. One heavy Eutaw clay was so adhesive to conventional plows, it had lain in sod for years. With the lubricated plow, we worked it."

Schafer described the lubricated plow as a moldboard plow with ports drilled in it that allow a lubricant to flow along its surface. The lubricant is an inexpensive solution of water and a biodegradable polymer which is harmless in the soil.

Along with moldboard plowing, chiseling under the row has become a traditional practice. Chiseling has many advantages. It breaks up the compacted layer, or hardpan, so crop roots can penetrate deeper into the soil and make use of subsoil moisture. Chiseling can increase yields when used in conventional farming, and it also fits into reduced-tillage conservation farming.

Agricultural engineer James G. Hendrick, also located at the National Tillage Machinery Laboratory, pondered the method of drawing the chisel through the soil by the sheer brute force of drawbar pull, and he became convinced that there was a more efficient way to get the job done. Consequently, Hendrick developed a rotary chisel concept in which the chisel is powered by the tractor's power-take-off shaft and pushes itself across the field. His concept of the powered rotary chisel is based on three considerations: (1) power can be better transmitted to the chisel by the drive line than by drawbar pull; (2) soil compaction can be reduced by eliminating the need for heavily weighted wheels on tractors; and (3) chiseling can be done in a timely manner because wet and muddy fields would not pose a problem due to the reduced draft developed by tractor tires.

Chiseling, subsoiling, or other forms of deep tillage move a lot of soil around. This may be bad. For one thing, these methods are slow, expensive, and require a lot of energy. Also, these very methods mix soils from various depths (horizons) which may result in undesirable physical and chemical conditions.

Soil scientist Charles B. Elkins, research leader, Soil and Water Research unit, Auburn, Ala., believes these problems can be avoided by making a very narrow slit in the hardpan. A narrow slit would require less energy than deep tillage and would not mix the soil from different horizons.

The insight that gave rise to the slit tillage concept arose from another concept: Tillage need not be performed by machinery at all—certain plants can do

Top and above, left: Video photography by Austin Mitchell helps agricultural engineer James Taylor document the effects of various tread designs on specific kinds of soil. (0383X191-13). Tread depth (soil compaction) measurements are another part of Taylor's analysis of soil and tire interactions. (0383X192-32)

Above, right: Agricultural engineer James Hendrick takes his rotary chisel for a spin. Deriving its power from the tractor, the chisel literally pushes itself across the field. (1078X1253-22)

An experimental blade designed to knife its way through hardened soil is examined by the chief developer of the slit tillage concept, soil scientist Charles Elkins of the ARS Soil and Water Research unit at Auburn University. (0383X330-20A)

Subjecting soil samples to precisely controlled pressures from a shearing device enables Auburn University graduate research associate Tim Nichols (left) and agricultural engineer Alvin Bailey to plot the relationships between soil stress and soil compaction. (0383X193-5A)

Replacing the driver? Agricultural engineer Robert Schafer presents tomorrow's farmers with the circuit board from a computerized guidance system for tractors and other farm machinery. Research shows that computer-controlled traffic across croplands can reduce soil compaction considerably. (0383X193-16A)

it. Research by Elkins and others at Auburn had shown that the deep-penetrating roots of bahiagrass could condition soils in such a beneficial way as to double cotton production on hardpan fields. Other work at Auburn concerns the development of tall fescue cultivars with superior ability to penetrate soil hardpans that restrict production of rowcrops such as cotton, corn, and soybeans.

But since using the grasses to penetrate hardpans might not always be desirable (planting grasses necessitates taking the land out of rowcrop production for several years), Elkins conducted an experiment in which he cut a narrow slit (2 to 3 mm wide by 38 cm deep) through the hardpan. Results of tests with soybeans were dramatic. Whereas soybean roots in no-till and conventional tillage plots did not penetrate the hardpan, roots of the soybeans in the slit-plant treatment grew through the hardpan and permeated the soil more than 1 m deep and 50 cm to each

side. By penetrating deep into the subsoil, the soybeans in the slit-plant treatment used subsoil water that carried them through a 5-week dry period.

"These tests," Elkins says, "strongly indicate the feasibility of developing a useful slit-plant farm implement. Such an implement would require much less energy than chisel subsoilers." Elkins is collaborating with the National Tillage Machinery Laboratory to investigate slit-plant machinery concepts.

Any discussion of tillage soon butts up against a paradox. We till, in a large measure, to correct a condition created by tillage and tillage machinery. Soil compaction, the central problem of tillage, does not usually exist in nature. But annual tillage and the associated wheel traffic cause soil compaction which requires more tillage to correct it.

Agricultural engineer James H. Taylor, who is research leader for traction and transport research at the National Tillage Machinery Laboratory, in a telling analogy, observes that "Road-building contractors like to till intensely and then compact it—sometimes with pneumatic tires. Many of our crop production systems follow the same sequence." Research is now directed toward avoiding the problem by limiting and controlling the traffic of machinery in the field.

"Simply put, controlled traffic is a term to designate a cropping system in which rootbeds and roadbeds are permanently separated," says Taylor, who is also national technical advisor for controlled traffic research.

The basic principles of controlled traffic have been tested and verified in soil bin studies. Some of the benefits of controlling traffic are: reduced tillage draft and consequent energy savings; improved timeliness of operations, which is especially crucial to double cropping; better tractive efficiency and mobility; and improved water infiltration rate and storage capacity.

As Taylor observes, "Anyone who has ever driven a pickup truck across a freshly plowed field is aware of the sinkage and drag on the vehicle. But if he crosses the field again and follows the ruts, he has a rather decent roadway." In such an instance, one can feel the excessive amount of energy needed to move through freshly tilled soil, and the relative ease of the second run over the ruts tells emphatically how much the soil has been compacted.

Studies of root development in soil compacted by heavy farm machinery show the need for a traffic control system to establish permanent rootbeds and roadways. (PN-7041)

Taylor notes that conservation tillage, which meets the needs of plants while protecting the soil with crop residues, is growing annually, and that random traffic across fields that are not to be retilled can lead to major problems of compaction, erosion, and reduced yields. However, controlled traffic combined with conservation tillage could lead to dramatic savings of soil and energy while maintaining or improving yields.

To aid in controlled traffic research, Schafer and his colleagues at Auburn developed automatic guidance concepts for tractors. The guidance system they used to test these concepts was based on a computer controller. Schafer predicts that automatic control systems for steering and other functions will be used on future agricultural machines. "Controlled traffic will lead logically and almost inevitably to automatic guidance," says Schafer.

The automatic guidance system, custom prescribed tillage, the lubricated plow, the rotary chisel, slit tillage, controlled traffic, conservation tillage—all of these and more will determine whether we live up to the idea, rooted deep in Western values, that we hold the land in stewardship and have an obligation to do more than exploit it for our own immediate gain.

Robert L. Schafer and colleagues are located at the National Tillage Machinery Laboratory, P.O. Box 792, Auburn, Ala. 36860. Charles B. Elkins is located in the Soil and Water Research Unit, 230 Funchess Hall, Auburn University, Auburn, Ala. 36849.—(By Bennett Carriere, New Orleans, La.) ■

100

Mastitis Diagnosed by Computer

Dairy cows need not endure mastitis long before treatment if the dairy farmer has a computer that will help diagnose the disease during milking, before visible signs appear.

A computerized dairy herd management system that includes this diagnostic feature is being developed by ARS and University of Illinois scientists. Agricultural engineer Hoyle B. Puckett says a subclinical infection can be detected within as few as three milkings.

Mastitis is an inflammation of the udder that is common in dairy cattle. If the computerized diagnostic feature becomes widely used, it could substantially reduce the estimated $2 billion that U.S. dairy farmers lose each year to veterinary costs and reduced production.

The system that graduate assistant Ashim K. Datta and agricultural engineer Errol D. Rodda helped Puckett design works on the principle that milk from an infected cow is a better conductor of electricity than milk from an uninfected cow. A further indicator of infection is a drop in milk production.

The researchers installed a flow meter on a milking machine that measures each one-tenth of a pound of milk that comes through the unit. They also installed temperature and conductivity probes in the lid assembly of the machine to monitor milk that comes from each of the cow's quarters. Conductivity of milk from each quarter is compared with that of milk from the other quarters, says Puckett.

Explaining the system further, Puckett says each cow's identity is recognized from information supplied by a transponder on the cow, through a central processing unit (CPU) equipped with a random access memory. The CPU flags indications of likely infections for the farmer's attention.

Data from each cow can be compared during every milking with her own historical data to detect abnormal changes, says Puckett. Milk conductivity may differ among cows for many reasons—breed, stage of lactation, the number of lactations, and milking interval.

Monitoring the milk throughout each of three consecutive milkings provides data that reliably enable detection of infected quarters. In the study, only 0.4 percent of analyses indicated that a quarter had mastitis when in fact it did not, says Puckett.

From among eight cows in the experiment, University of Illinois dairy scientist Sidney L. Spahr found that only one cow had mastitis and it was in one quarter with a *Streptococcus uberis* infection. He obtained somatic cell counts in addition to bacteriological data.

"Numerous other studies have established conductivity measurements as reliable indicators of mastitis," says Puckett, "but in those studies researchers measured conductivity with apparatus outside the normal flow of milk in the parlor. We developed an inline system to quickly and efficiently measure conductivity without disrupting the milking operation."

Monitoring cows for indications of mastitis is only a part of the computerized dairy herd management system that the scientists are developing. The system's main purposes are to help dairy operators conduct the milking operation efficiently, keep records, improve the herd, control feeding according to milk production, and identify animals needing attention.

Hoyle B. Puckett is located in Rm. 226, Agricultural Engineering Bldg., 1208 W. Peabody Dr., University of Illinois, Urbana, Ill. 61801.—(By Ben Hardin, Peoria, Ill.) ■

Science and our Resource Heritage

Twenty-Five Years of Stubble Mulching

Twenty-five years of stubble mulching left nearly 6 tons more organic matter per acre in the top 18 inches of soil than conventional tillage did, according to Armand Bauer, soil scientist at the Northern Great Plains Research Laboratory at Mandan, N. Dak.

"Our research in southwestern North Dakota shows that just the nitrogen in that much organic matter is worth around $178," Bauer says. "And spring wheat yields, cropping every other year, were 26.7 bushels per acre for the stubble mulch system and 24.7 for the conventional system."

In the semiarid northern Great Plains, stubble mulching, a tillage system which leaves the wheat straw on the surface after harvest, has been recommended for years, but many farmers are skeptical that stubble mulching will provide any advantage in production or have an effect on soil organic matter. And research results concerning the question over long periods have not been available.

Looking for a way to find out what was really happening, Bauer and soil scientist Al Black, in cooperation with the Soil Conservation Service, selected adjacent farm fields in Grant County that had been under the same tillage systems for 25 years. One farm used stubble mulching, and adjacent farms conventional tillage methods.

This provided an ideal opportunity to evaluate the effects of the different tillage methods on organic matter, Bauer says.

All together, 576 soil samples were taken from 36 different fields: 12 stubble mulched fields, 12 conventionally tilled, summer fallowed fields, and 12 hay or pastured fields that had never been cultivated.

Sampling locations on each farm included moderately coarse-textured soil, medium-textured soil, and moderately fine or fine-textured soil.

To evaluate what had been happening with organic matter, the scientists measured carbon and nitrogen in the top 18 inches of soil. The results show that after 25 years, stubble mulched soils averaged 14.5 percent more carbon (6,750 pounds per acre), and 12.2 percent more nitrogen (711 pounds per acre), than conventionally tilled soils.

"Most of the difference," Bauer says, "is due to decreased wind erosion with stubble mulch tillage methods on summer fallowed fields." In an alternate spring wheat-summer fallow sequence, a crop is growing only 3 months and fallowed for 21 months.

Under the stubble mulch system, fields were tilled with an undercutter during the summer fallow period with little disturbance to the soil surface. Only about 5 percent of the residue was incorporated into the soil. Fields will tilled two or three times during the fallow year with 32-inch sweep blades, just below the soil surface, leaving the grain stubble standing and cutting off weed roots.

Under the conventional tillage system the land was either plowed, or some other tillage tool, such as a chisel plow or disk, was used. This practice covered most of the crop residue during the first tillage operation of the summer fallow.

Under both tillage systems a moldboard plow-packer-pony press drill was used in tandem for spring seeding in almost all cases. The conventionally tilled acres received an average of 118 pounds more nitrogen fertilizer over the 25 years than did the stubble mulched land.

"Moderately coarse-textured soils are the most susceptible to wind erosion," Bauer says, "and benefit the most from residues on the soil surface during the summer fallow period."

Only 5 to 8 percent of the residue returned to the soil eventually stays as organic matter. It takes a long time to build up organic matter after its level has fallen significantly, Bauer says. In the case of these moderately coarse-textured soils, it would take the organic matter formed from about 94 tons of crop residue per acre on the conventionally tilled lands to bring them back up to the organic matter levels of the stubble mulched land.

"The difference in organic matter levels between the two tillage systems will continue to widen," Bauer says. "Erosion is much greater under conventional tillage methods, and production on the conventionally tilled land is less, so the amount of residues returned to the soil is less than on the stubble mulched fields."

Above: Stubble mulched field on a Grant County, N. Dak., farm from which samples were removed for carbon and nitrogen analysis. (PN-7040)

Left: Soil scientist Armand Bauer and research technician Cindy Gustin count test field wheat heads to estimate grain yield and straw-to-grain ratio. (1080X1238-4)

The long-term productivity of conventionally tilled soils with lower organic matter can be increased to the level of stubble mulched soils only by producing more crop residue, halting erosion, and adding more nitrogen fertilizer, he says. Nitrogen now costs as much as 25 cents a pound and is expected to go up rapidly along with the price of natural gas, the main raw material now used to produce nitrogen fertilizer.

At that price, the 711 extra pounds of nitrogen per acre in the stubble mulched land is worth about $178. That is about half the price of an acre of farm land at 1982 prices in southwestern North Dakota, Bauer says.

The greatest nitrogen losses occurred on conventionally tilled, moderately coarse-textured soils. Over the 25-year period, they lost 1,474 pounds more nitrogen than did the same soil type under stubble mulching. That is 59 pounds an acre each year, $14.75 worth of nitrogen if it is 25 cents a pound. That is $368 over 25 years, about the price of the land.

Nitrogen losses were less from fine-textured soils, probably because they are less susceptible to wind erosion than the moderately coarse-textured soils, and thus the differences in losses between the two tillage systems were less. However, over the 25 years, even on the fine-textured soils, nitrogen losses were 21 pounds more per acre each year under conventional tillage than under stubble mulching.

"This study shows that a higher level of organic matter can be maintained with stubble mulch tillage practices," Bauer says. "Yields will be higher and production costs lower."

"Put more simply," he added, "we can maintain long-term soil productivity at a higher level with stubble mulching than with conventional tillage."

Armand Bauer is located at the Northern Great Plains Research Laboratory, P.O. Box 459, Mandan, N. Dak. 58554.—(By Ray Pierce, Peoria, Ill.) ■

100

945

Breeding Plan for Bees [1-2],

The use of artificial insemination in a scientific manner by beekeepers has the potential to create an elite new family of honey bees.

"Our goal is to develop a new scientific basis for breeding bees to be gentle, produce lots of honey, overwinter well and resist disease," says ARS entomologist Eric H. Erickson, Madison Wis.

Ultimately, new lines of gentle bees could help counter the threat of Africanized bees that are migrating toward the United States through Central America, Erickson says.

Thirty-five queen honey bees, selected from throughout the United States, are the basis for the experiment conducted at the University of Wisconsin-Madison.

"Artificial insemination (AI) is a means by which we may be able to maintain a closed population of 35 colonies that continually produce viable broods," says Erickson. "AI will keep queens isolated from drones that may not have the genetic qualities we want in our bee populations."

From a natural mating, undesired genetic qualities are likely to appear because a queen may mate with several drones of questionable family background from colonies a mile or more from her hive. Once she is fertilized there's no more opportunity for mating with a better pedigreed candidate. She will never mate again.

Artificial insemination prevents the possibility of any natural mating. It's done with a steady hand under a microscope on queen bees that have been anesthetized with carbon dioxide.

From each new generation of bees in each colony, Erickson and entomologist Robert E. Page will select queens to be artificially inseminated with a mixture of semen from the 35 colonies. That's the number of queens that their computer mating studies show is needed for closed populations to avoid excessive inbreeding.

Inbreeding may cause shot brood, a situation in which the colony loses some of its viability because fewer than normal numbers of fertilized eggs develop into workers. Instead, many of the fertilized eggs develop into abnormal bees known as diploid males—

Honey bees on a comb, as seen through the glass of an observation hive. Artificial insemination may permit genetic improvement of the honey bee. (0982X1130-19)

bees with homozygous sex alleles. Workers, or heterozygous females, rid the colony of the abnormal males by eating them as soon as they are hatched.

Normal males, or drones, develop only from unfertilized eggs.

Until now, shot brood has been the complication that has kept artificial insemination from becoming a powerful tool for most kinds of selective breeding. To avoid shot brood, USDA scientists began a hybrid bee breeding program using AI in 1943. In order to produce excellent hybrids,many inbred lines had to be selected, maintained and tested, said Erickson, but the lines were easily lost.

Despite failures, however, there have been successes. Agricultural research technician Emmett R. Harp and Erickson developed a line of bees that are extraordinarily gentle and well suited for beekeeping around urban areas. Release of this line to the industry is planned for 1983.

Until the U.S. Congress passed the 1981 farm bill, the USDA could turn over plant germplasm to private industry but it could not release bee germplasm that it had developed in the course of research.

"The new line of bees are good honey-makers," Erickson says. "Generally, gentle bees are just as productive as more aggressive strains."

The notorious Africanized or so-called "killer bees" are migrating toward the United States via Central America.

"This bee, while not as aggressive as some reports would suggest, is a source of concern as its presence in the United States could impose economic hardships on our beekeepers," says Erickson. "This is because with it will come a new bee disease, caused by a Varroa mite, and undesirable behavior problems associated with honey production and crop pollination."

If the mongrels do reach the Southern United States, perhaps their natural interbreeding with new lines of gentler bees could reduce their threat to the beekeeping industry, says Erickson. And advances in the use of AI in closed bee populations could enable establishment of African-gene-free germplasm reservoirs for restocking apiaries that may be despoiled.

If research shows the closed population approach to bee breeding produces high-quality queens, Erickson says the methodology would be such that any bee breeder could conduct a selection program. Moreover, their improved bees may be kept for many years to come.

Eric H. Erickson is located at the Department of Entomology, University of Wisconsin, Madison, Wis. 53706.—(By Ben Hardin, Peoria, Ill.) ■

100

Nitrogen Needs of Sugarbeets Under Reduced Tillage

Sugarbeets grown under reduced tillage conditions will probably require the same amount of nitrogen fertilizer to maximize sugar yields as is now required under current tillage practices.

Soil scientist Ardell D. Halvorson measured nitrogen requirements for beets under three tillage systems: conventional (all previous crop residue is mixed into the soil), strip-till (only residue where the beets will be planted is mixed), and no-till (no residue is mixed with soil).

The tests were conducted for 3 years at the Northern Plains Soil and Water Research Center, Sidney, Mont. Previous to this research, no one knew if the nitrogen should be decreased, increased, or kept the same.

Reduced tillage operations are gaining popularity with growers because they require less fuel. The fewer trips made across a field the less fuel a farmer has to buy.

Ardell D. Halvorson is located at the Northern Plains Soil and Water Research Center, P.O. Box 1109, Sidney, Mont. 59270.—(By Dennis Senft, Oakland, Calif.) ■

45

Better Biocontrol, Less Insecticide [1-2]

Reliance on the insecticide, aldicarb, for controlling the Colorado potato beetle could be significantly lessened with the development of a technique to mass-rear a bettle parasite, the tachnid fly.

Entomologist George Tamaki and biological technician Richard L. Chauvin, Yakima, Wash., along with Ting Hsiao of Utah State University, Logan, have been seeking natural enemies to reduce beetle numbers and damage, and ways of making these enemies more effective.

They found that tachnid flies, similar in appearance to the common housefly, parasitize Colorado potato beetle larvae. However, under natural conditions, the flies emerge too long after the beetles to have any real economic impact. With their new mass-rearing technique, the researchers can now correct this timing problem and obtain earlier, far more effective tachnid fly emergence.

Colorado potato beetle *(Leptinotarsa decemlineata)* on a potato leaf. The beetle is ⅜-inch (9 mm) long. (0483X384-1A)

To further change the environment of a potato field so that it favors the parasitic fly over the pestiferous beetle, the researchers are testing the use of diflubenzuron, an insecticide so selective it affects the Colorado potato beetle but not tachnid flies.

The Colorado potato beetle is a big problem for potato producers all across the United States and throughout the rest of the world as well. Consuming foliage which weakens and eventually kills the potato plants, an infestation of Colorado potato beetles can easily wipe out an entire field of plants.

Standard control in recent years has been the application of the systematic insecticide, aldicarb, to the soil in potato fields. Potato plants take up the chemical and distribute it to the leaves which the beetles feed on. However, in some parts of the country, not all of the aldicarb has been used by the plants. Some has leached down through the soil and into the water table, raising safety concerns.

To make matters worse for growers, the Colorado potato beetle shows resistance to aldicarb in Europe and in parts of the Eastern United States.

While the testing of diflubenzuron is being continued and further studies of Coloardo potato beetle biology are still underway, the crucial technique for mass-rearing tachnid flies has been fully developed and is described in detail in a publication.

Copies of this publication can be obtained by writing to Tamaki at the Yakima Agricultural Research Laboratory, 3706 West Nob Hill Blvd., Yakima, Wash. 98902.—*(By Lynn Yarris, Oakland, Calif.)* 100

Yeast Ferments Cellulose to Alcohol

Wood chips, paper, straw, stalks, and other plant residues could be materials from which alcohol for fuel and industry are made. *Candida wickerhamii,* in the ARS Culture Collection, could simplify the process, with a little preparation of the woody materials.

In preparation, the wood chips and other plant residues—containing cellulose—undergo a process called acid hydrolysis that partially breaks the cellulose down into cellodextrins. Cellodextrins are complexes of the glucose sugar molecule. Ordinary yeasts can not make alcohol from cellodextrins. They must have the simple glucose.

The yeast was screened from the collection at the Northern Regional Center in Peoria, Ill., by Shelby N. Freer and Robert W. Detroy. The scientists are studying ways to make alcohol for fuel and industrial raw material from cellulose and other plant components.

Using the yeast, scientists produced 29.2 grams per liter of ethanol from 54 grams per liter of cellodextrins per quart in 3 to 4 days.

Neither glucose nor ethyl alcohol is currently made commercially from cellulose. In the fermentation process now used, glucose from starch is metabolized by yeast, producing carbon dioxide and alcohol.

One way to obtain glucose from cellulose is by acid hydrolysis of the wood products, a chemical process; however, this method can form products that are toxic to the yeast. "If milder hydrolysis procedures were developed so that cellodextrins were the major product, unfermentable products and toxic byproducts would be reduced," Freer says.

The yeast was discovered in Italy, where it was isolated from silage made of olive husks, molasses, and whey.

Shelby N. Freer and Robert W. Detroy are located at the Agricultural

U.S. Government Printing Office
Public Documents Department
Washington, D.C. 20402
Official Business

Postage and Fees Paid
U.S. Department
of Agriculture

G—95

Microbiology Research Laboratory, Northern Regional Research Center, 1815 N. University, Peoria, Ill. 61604.—(By Dean Mayberry, Peoria, Ill.) ■

Predicting Salt-Leaching from Stripmines

Basic information on how much salt will leach from stripmined areas can be obtained by analyzing drill samples before actual mining begins.

Soil scientist Herbert R. Gardner says, for shale, more than 95 percent of all salts released by stripmining come from shale particles 1/2 millimeter (about 1/50 inch) or less in diameter. In gathering information for mining permits, particles larger than 1/2 mm can be discarded and predictions on how much salt will leach from reclaimed lands will still be accurate.

Permits for surface mining generally require submission of information on potential salt pollution of ground water and streams after mining. Salts such as calcium and magnesium sulfate are released when water infiltrates material that has been fractured by the massive earth-moving operations required to get at coal or uranium buried underneath.

After separating out the 1/2 mm particles obtained from air-drilled chip samples, Gardner soaks them in water and measures quantities of salts that leach into the water. The most accurate method of separating particles is by wet sieving. Dry sieving is not accurate because up to 50 percent of the smaller particles can cling to larger particles and be discarded.

The amount of salt that is released from a mine site is related to the surface area of the spoil material.

Herbert R. Gardner is located at the Federal Building, P.O. Box E, Fort Collins, Colo. 80522.—(By Dennis Senft, Oakland, Calif.) ■

Cooling Off the Codling Moth

Revelation by ARS researchers that codling moths tend to be monogamous in cooler climates and polygamous in warmer climates, and that older males are more sexually competitive than younger males, should enhance the effectiveness of such techniques as sterile insect release and mating disruption for controlling moth populations.

Disrupting reproduction is an environmentally safe and effective approach to controlling the populations of insect pests. However, to use this approach, a thorough knowledge of a specific pest's mating behavior is essential.

The codling moth is a pest of deciduous fruit important to U.S. growers because infestations prevent exports to Japan and other big fruit markets. Entomologist Franklin Howell, Yakima, Wash., has been studying the codling moth's mating behavior and has found information that, in addition to helping control programs, will also benefit future research on the pest.

Says Howell, "Our studies show that the sterile insect release technique should be more effective in cooler temperatures (daily minimum under 60° F) when the females are essentially monogamous. Releasing 2-day-old males will be more effective than releasing 1-day-old males because the older males produce large spermatophores (capsules of sperm) more consistently. Females receiving a large spermatophore usually discontinue mating, while females receiving small spermatophores may, if temperatures are warm and the ratio of males to females is high, remate."

Howell says the release of sterile males conditioned to produce large spermatophores would be the most effective way to suppress moth reproduction, but this would require care, as sterilization tends to reduce spermatophore size.

Franklin Howell is located at the Yakima Agricultural Research Laboratory, 3706 W. Nob Hill Blvd., Yakima, Wash. 98902.—(By Lynn Yarris, Oakland, Calif.) ■